

Portable Particle Counters/Sensors Initial Screening Tests

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Abstract: The Army AMCOM Hydraulic Contamination Integrated Product Team (IPT) is investigating the possibility of integrating a portable particle counter or sensor on their Air Ground Portable Units (AGPU). An AGPU is a military version of a portable filter cart used for flushing/cleaning helicopter hydraulic systems. To ensure the system is clean, a sensor mounted on the AGPU will monitor the cleaning cycle for completeness and reliability. In addition, the particle counter internal to the AGPU negates the need to take samples for laboratory analysis. Flight line conditions have the potential to add contamination while taking samples.

Any sensor selected for use on the AGPU must be capable of measuring fluid cleanliness at ~65psi from the return line of the aircraft. Since the hydraulic fluid will have entrained air bubbles, the sensor must also be capable of accurately measuring particulate contamination in the presence of air bubbles. The sensor system can either remove or discount the air bubbles.

The Army IPT requested assistance from the Joint Oil Analysis Program Technical Support Center (JOAP-TSC) for the initial screening of several particle-counting units. For the screening process, the JOAP-TSC recommended three initial tests for the manufacturers. The tests were performed at the JOAP-TSC.

1. Provide documentation that the unit has been calibrated according to and meets ISO 11171 Calibration. The Army IPT wants an instrument/sensor with the capability to meet the ISO 11171 and ISO 4406-1999. Companies were asked to provide documentation that their instrument has passed the required tests for the ISO 11171 calibration – verify flow rate, accuracy, coincidence error, sizing calibration, resolution, etc.
2. Analyze Medium Test Dust (MTD) reference fluid five times with aeration under 65psi to simulate the air bubbles that will be found in the aircraft to AGPU return line. In addition, MTD reference was analyzed without bubbles (fluid was sonicated) at 65psi to demonstrate laboratory conditions. Calculate mean, standard deviation, relative standard deviation and D_Q .
3. Analyze used hydraulic fluid five times with aeration under 65psi to simulate air bubbles. Calculate mean, standard deviation and relative standard deviation. In addition, the used fluid was analyzed without aeration under 65psi.

The JOAP-TSC felt that any manufacturer’s instrument that passes these three screening tests, would be a good candidate for further engineering/practical evaluation by the Army.

The results of the initial screening tests validated the desirability to screen available products for accuracy and suitability prior to procurement.

Key Words: Hydraulic fluid, ISO 11171, JOAP; particle counting, sensors

Instrument Overview: Most particle counters use light or infrared energy to illuminate individual particles and are referred to as light obscuration particle counters. The amount of light blocked by a particle is detected by a photodiode and translated into an electric output signal; the frequency and amplitude of the output signal provide particle size and concentration information. An integrated flow rate meter measures the flow rate, which is required to determine the cleanliness class.

Testing Results: Several manufacturers demonstrated their product and performed the screening tests. Due to contractor sensitive information, the actual companies tested will not be identified other than by Company A, B and C.

1. Documentation:

- Company A provided the ISO 11171 Calibration documentation after testing. The documentation included the requested information: tables (and some plots) for coincidence error, accuracy, sizing calibration, flow rate, resolution and a certificate.
- Company B did not provide the ISO 11171 Calibration documentation. A summary sheet was provided after testing. It did not provide the requested information.
- Company C provided the ISO 11171 Calibration documentation before testing. The documentation included the requested information: tables (and some plots) for coincidence error, accuracy, sizing calibration, flow rate, resolution and a certificate.

Size >um (c)	Mean Particle Concentration (particles/mL)	Min Allowed	Max Allowed
4	6121.9	5091	7470
5	3687.3		
6	2234.6	1880	3092
10	473.7		
14	160.1	119	256
21	40.1	17	111

Table 1: Partistan 2806, Lot 11 Certification Data

2. MTD standards: The MTD reference fluid used was Conostan Partistan 2806, Lot #11. Table I provides certification of the particle concentrations by size for Lot #11. Table II includes portions of Table 8, ISO 11171 that indicates the maximum allowable percent differences in particle counts between runs. Table III provides the test results of aerated MTD for the three candidate companies.

If the mean (average # of counts) is greater than or equal to:	but less than:	Then the max. DQ for individual samples is:
10,000		11
5,000	10,000	11.3
2,000	5,000	11.9
1,000	2,000	13.4
500	1,000	15.6
200	500	19.3
100	200	27.5

Table 2: (Portions of) Table 8, ISO 11171, Maximum Allowable Percent Differences in Particle Counts Between Runs.

Reference Material (Partisan 2806, lot #11) - analyzed 5 times. Rotated 30 min, shaken 2 min, no sonication												
Company	A	B	C	A	B	C	A	B	C	A	B	C
Micron size	4 u	4 u	4 u	6 u	6 u	6 u	14 u	14 u	14 u	21 u	21 u	21 u
2806-1	6407.5	5983.9	18236.1	2593.4	2635.5	3736.3	159.8	612.5	336.6	47.3	503.5	N/A
2806-2	6440.4	5670.4	13968.0	2643.0	2253.5	2744.9	172.3	201.6	246.4	46.7	99.6	N/A
2806-3	6406.0	5694.2	11661.4	2587.4	2208.1	2281.6	159.0	124.6	182.4	43.3	26.1	N/A
2806-4	6476.5	6079.3	10366.0	2618.3	2569.8	2010.2	168.3	492.2	187.5	46.4	378.9	N/A
2806-5	6473.0	5718.1	8732.8	2659.0	2216.6	1605.7	164.4	145.8	120.9	42.6	43.8	N/A
sum	32203.46	29145.90	62964.28	13101.08	11883.5	12378.7	823.76	1576.7	1073.82	226.34	1051.9	N/A
mean	6440.69	5829.18	12592.86	2620.22	2376.7	2475.75	164.75	315.34	214.76	45.27	210.38	N/A
2806 Lot 11	6121	6121	6121	2234	2234	2234	160	160	160	40	40	40
min allowed*	5091	5091	5091	1880	1880	1880	119	119	119	17	17	17
max allowed*	7470	7470	7470	3092	3092	3092	256	256	256	111	111	111
ST DEV	34.02	188.59	3689.99	30.93	208.27	817.43	5.66	222.29	81.31	2.15	216.97	N/A
Rel ST DEV	0.53%	3.24%	29.30%	1.18%	8.76%	33.02%	3.43%	70.49%	37.86%	4.76%	103.13%	N/A
Dq=	1.09%	7.01%	75.47%	2.74%	17.98%	86.06%	8.10%	154.72%	100.43%	8.92%	226.92%	N/A
Dq allowed	11.30%	11.30%	11.30%	11.90%	11.90%	11.90%	27.50%	19.30%	27.50%	N/A	N/A	N/A

Table III: Results from testing MTD Reference Fluid. The results in bold fail.

*Minimum and Maximum values allowed for reference material

- Company A: The unit accurately evaluated the reference material with and without bubbles and passed D_Q for all test runs. Since the unit passed with bubbles, only one run was performed for the sonicated (non-aerated) sample, which also passed.
- Company B: The unit did not pass ISO standards (D_Q) for the aerated sample (6u and 14u failed) or the sonicated (non-aerated) sample (14u failed).
- Company C: The unit did not pass ISO standards (D_Q) for the aerated sample (4u, 6u and 14u failed) or the sonicated (non-aerated) sample (4u, 6u and 14u failed).

3. Used Fluid (Mil-PRF-83282): The hydraulic fluid used in the helicopters is Mil-PRF-83282. A 2-gallon container of used Mil-PRF-83282 was provided by AMCOM IPT from a helicopter under maintenance. Table IV provides the test results of used MIL-PRF-83282 for the three candidate companies.

- Company A: Since the particle counting unit from Company A passed the MTD (with and without bubbles); its results were taken as the benchmark for the used oil. The relative standard deviation was less than 15% for all size ranges (3% for 4u, 10% for 6u, 15% for 14u and 13% for 21u). There were less than 100 particles for the 14u and 21u size ranges.
- Company B: The values for the Company B unit were within 11% of the benchmark: 0% for 4u, 11% for 6u and 0% for 14u. The relative standard deviation however was 45% for 4u, 28% for 6u, 51% for 14u and 83% for 21u. There were less than 100 particles for the 14u and 21u size ranges.
- Company C: The values for the Company C unit were significantly off from the benchmark; 538% for 4u, 427% for 6u, and 530% for 14u. The relative standard deviation was 42% for 4u, 31% for 6u and 35% for 14u.

Used MIL-PRF-83282 - analyzed 5 times. Shaken 2 min, no sonication												
Company	A	B	C	A	B	C	A	B	C	A	B	C
Micron size	4 u	4 u	4 u	6 u	6 u	6 u	14 u	14 u	14 u	21 u	21 u	21 u
2806-1	1261.8	23231.0	14061.4	318.5	4416.0	2592.6	33.3	633.0	329.6	12.5	347.0	N/A
2806-2	1254.7	10472.0	7915.5	308.9	2668.0	1812.5	35.2	301.0	215.0	14.2	111.0	N/A
2806-3	1343.3	10086.0	6851.2	378.3	2561.0	1567.3	39.0	274.0	184.9	12.8	99.0	N/A
2806-4	1233.3	10425.0	5980.1	294.2	2606.0	1249.3	28.5	238.0	148.5	10.5	79.0	N/A
2806-5	1295.3	9958.0	5937.6	338.0	2511.0	1411.5	27.6	228.0	162.2	10.8	65.0	N/A
sum	6388.52	64172.00	40745.72	1637.84	14762.00	8633.13	163.52	1674.00	1040.22	60.74	701.00	N/A
mean	1277.70	12834.40	8149.14	327.57	2952.40	1726.63	32.70	334.80	208.04	12.15	140.20	N/A
mean/ml		1283.44			295.24			33.48			14.02	40
ST DEV	42.92	5815.99	3401.83	32.49	820.22	526.75	4.75	169.22	72.46	1.53	116.96	N/A
Rel ST DEV	3.36%	45.32%	41.74%	9.92%	27.78%	30.51%	14.52%	50.54%	34.83%	12.59%	83.42%	N/A
	*Company B: Results per 100 ml											

Table IV: Results from testing used MIL-PRF-83282.

Other Capabilities Demonstrated:

- Company A: The internal printer provided results for all samples analyzed. ISO Codes and SAE codes are automatically provided on the printout and NAS and NAVAIR codes in the data file.
- Company B: Downloading of data (which is a stated capability) for the bench top unit was not demonstrated. The data had to be typed into a spreadsheet. The unit is not capable of converting stored data from one standard to another – you must choose the standard of interest. An ISO rating is provided on the screen.
- Company C: Only three particle channels are reported – ISO states a minimum of 4 channels are required. In a five run analyses, only the last analysis is printed. The data can however be retrieved electronically. NAS micron sizes are provided in the data file.

Conclusions: Two units did not meet stated test objectives. The Company A unit passed all three preliminary tests and is a good candidate for further engineering/practical evaluation by the Army. The results of the initial screening tests validated the desirability to screen available products for accuracy, repeatability and suitability for application prior to procurement.

References:

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